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EFFECT OF DATE OF HARVEST ON YIELD AND MILLING QUALITY OF RICE[1]

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INTRODUCTION

The aim when growing a commercial rice crop is to obtain high acre yields of high milling quality that may be sold at a profit. To do this it is necessary to harvest the crop at the right stage of maturity. If the crop is harvested when immature, field yields are reduced, and the breakage in milling is excessive, because of the light, chalky kernels.

Some rice is harvested purposely before it has reached the proper stage of maturity, because the growers wish to sell at the premium price that often is paid by mills for the first lots of new-crop rice. At other times growers harvest too early because they are anxious to complete harvesting while the weather is favorable and before bad weather comes. But a great deal of rice is harvested each season either too early or too late to produce rice of high milling quality merely because no definite method has been adopted to determine when the crop should be cut.

Several factors affect the milling quality and the numerical grade of rough rice. They should be kept in mind. To produce rough rice of high milling quality and of high numerical grade, seed should be sown that is clean, viable, and free from mixtures of different types, of obnoxious weed seeds, and of red rice. Fields should be irrigated and drained at the right time. The crop should be harvested at the right stage of maturity. When harvested with a binder, the rice should be shocked promptly in such a way that it will cure satisfactorily before it is threshed. The crop should be threshed as soon as the kernels are well cured.

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[1] The data presented in this circular were obtained independently by the Bureaus of Agricultural Economics and Plant Industry.

MILLING QUALITY AS IMPORTANT AS GRADE

The commercial value of a given lot of rough rice depends largely upon its milling quality. The term milling quality, as used in the rice trade and in the official standards of the United States for rough rice, refers to the percentage of whole kernels and total milled rice that is obtained from a given quantity of rough rice, under average milling conditions. Rough rice that gives a high percentage of whole kernels when milled is said to be of high milling quality. As practically all rough rice sold by farmers is eventually milled, the buyers stress the importance of milling quality more than any other single factor.

When a lot of rough rice that has been produced in the Southern States is graded according to the official standards it is first classified as to variety or type, and is assigned a numerical grade based on factors other than milling quality. Then the milling quality is determined and stated as a part of the grade designation.

Two lots of grade No. 1 rough rice may differ substantially in milling quality and in market value. A lot of grade No. 2 rough rice may even be of higher milling quality than a lot of grade No. 1, because factors other than milling quality determine the numerical grade. So growers should attempt to produce rough rice that is of high numerical grade as well as of high milling quality.

It is an established fact that the moisture content of rough rice at the time of milling largely determines the yield of whole kernels. The milling quality, as a general rule, improves as the moisture content of the rough rice decreases to about 14 percent. To obtain the best results the moisture should be reduced gradually. If kernels are dried much below 14 percent of moisture they are hard. In milling such kernels it is difficult to remove the bran, therefore it is necessary to scour severely and this causes excessive breakage.

Moisture tests are made at rice-grading laboratories and at some rice mills and warehouses.

ASCERTAINING THE BEST TIME TO HARVEST

The most troublesome problem connected with producing a crop of rice has been to ascertain the proper stage of maturity at which the crop should be cut to produce maximum acre yields of high milling quality.

To determine the best time to harvest rice, the United States Department of Agriculture and some of the State agricultural experiment stations have been conducting a series of investigations. They are here reported and conclusions are given on page 19.

STUDIES AT RICE EXPERIMENT STATIONS

Cooperative studies were conducted by the Bureau of Plant Industry at the Rice Branch Experiment Station, Stuttgart, Ark., and at Texas Agricultural Substation No. 4, Beaumont, Tex., during the 3-year period from 1932 to 1934. At Stuttgart, Caloro, a short-grain, Early Blue Rose, a medium-grain, and Edith, a long-grain variety; and at Beaumont, Caloro, Edith, and Supreme Blue Rose, a medium-grain variety, were used in this study. The varieties were sown in duplicate or triplicate three-row plots 16 or 16½ feet long and the rows were spaced 1 foot apart. At Stuttgart, duplicate plots of each variety were harvested daily during 20-day periods, and at Beaumont triplicate plots of each variety were harvested on alternate days during 32-day periods. Owing to differences in maturity of the four varieties, the 20- and 32-day harvesting periods were not necessarily on the same dates. The center rows of the duplicate or triplicate three-row plots were harvested for yield.

The percentage of moisture in the rough rice at threshing time was determined at Stuttgart in 1932 and 1933 by harvesting, curing, and threshing the border rows of each of the duplicate plots. At the time the center rows were harvested, rice from the border rows of each plot was stripped from the panicles (heads) and placed in moisture-proof containers and the percentage of moisture was determined as soon as possible chiefly with Brown-Duvel moisture testers. The harvested rice was placed in an open shed and when dried to a moisture content of about 14 percent was threshed and the yields were determined. Each year the threshed samples were stored under like conditions until tests for milling quality were made with the Smith shelling device.

The average kernel weight at Stuttgart was determined by weighing 200 to 250 kernels in lots of 25 to 100, and at Beaumont by weighing 100 kernels from the Smith shelling device in 1932 and kernels from which the hulls were removed by hand in 1933 and 1934.

The factors studied included the percentage of moisture in the rice when harvested, the air-dried kernel weight, the acre yield of grain, the ratio of grain to straw, the germination of the seed, and the milling quality. Correlation coefficients were computed by the method described by Wallace and Snedecor.[2]

RESULTS AT THE RICE EXPERIMENT STATIONS

MOISTURE CONTENT

At each station the rice varieties were first harvested when they were decidely too immature to produce maximum field yields of high milling quality. At this time most of the panicles (heads) of each variety had turned down but many of the kernels were in the milk and soft-dough stages. The harvesting period, however, extended over sufficient time to include fully mature and probably overripe rice of each variety. Since the data at Stuttgart and at Beaumont show essentially the same trends only data from Stuttgart are shown in the illustrations.

The average moisture content of the three varieties harvested daily during the 3-year period 1932–34 is shown in figure 1. During the first 8 days of the harvesting periods the percentage of moisture in the rice decreased rapidly, after which the decrease was more gradual but continued to the end of the harvesting periods.

The average moisture content of the three varieties differed considerably during the first 8 days of the harvesting periods, but thereafter it was much the same on each harvesting date. During the first 8 days of the harvesting periods the average percentage of moisture in Caloro was considerably higher than that of Early Blue Rose, and Early Blue Rose had a higher moisture content than did Edith.

At Beaumont the average moisture content of the rice on the first dates of harvesting was for Caloro 36.0, for Supreme Blue Rose 39.9, and for Edith 53.7 percent, while on the last dates of harvesting the average was for Caloro 16.7, for Supreme Blue Rose 18.8, and for Edith 22.0 percent. The average moisture content of the three varieties on the last dates of harvesting at Beaumont was decidedly lower than that on the last dates of harvesting at Stuttgart.

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[2] WALLACE, H. A., and SNEDECOR, G. W. CORRELATION AND MACHINE CALCULATION. Revised by G. W. Snedecor. Iowa State Col. Off. Pub. 30, No. 4, 71 pp., illus. 1931.

The percentage of moisture for each year and the average percentage for the 3-year period when grouped by 5-day periods at Stuttgart, and for the 2-year period grouped by 4-day periods at Beaumont, are shown, for each variety, in table 1. At both stations the average percentage of moisture in the rice decreased rapidly during the first 10 to 12 days of the harvesting periods; thereafter, the decrease was more gradual but continued to the end of the harvesting periods.

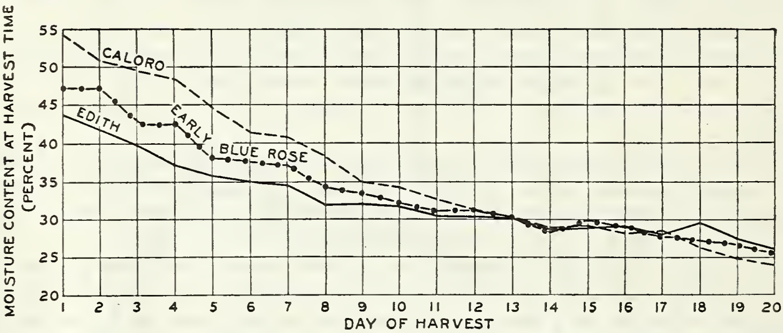

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FIGURE 1.—Average percentage of moisture in rice harvested daily at Stuttgart, Ark., 1932–34.

TABLE 1.—*Percentage of moisture in four varieties of rice harvested by 5-day or 4-day periods, Stuttgart, Ark., and Beaumont, Tex., 1932–34* [1]

Locality and period No.	Caloro				Early Blue Rose [2]				Edith			
	1932	1933	1934	Average	1932	1933	1934	Average	1932	1933	1934	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Stuttgart, Ark.:												
1	51.6	46.8	50.5	49.6	43.3	44.7	42.3	43.4	38.6	44.5	35.8	39.6
2	41.3	35.2	37.3	37.9	35.0	34.7	35.0	34.9	32.3	33.7	33.0	33.0
3	32.1	30.5	28.5	30.3	29.6	30.6	29.9	30.0	28.7	30.1	29.9	29.6
4	26.0	28.5	[3] 23.3	25.9	25.7	29.1	25.9	26.9	25.7	29.4	28.3	27.8
Beaumont, Tex.: [2]												
1	------	35.1	36.0	35.6	------	41.0	35.4	38.2	------	50.3	[4] 36.3	43.3
2	------	30.9	30.8	30.8	------	31.6	30.4	31.0	------	49.9	31.5	40.7
3	------	28.5	25.9	27.2	------	28.5	26.8	27.7	------	32.0	29.6	30.8
4	------	24.4	23.1	23.8	------	27.1	[4] 25.6	26.4	------	29.7	[4] 26.7	28.2
5	------	23.2	22.3	22.8	------	26.8	23.9	25.4	------	28.1	[4] 24.5	26.3
6	------	18.2	18.5	18.4	------	23.7	19.3	21.5	------	26.8	23.8	25.3
7	------	16.5	15.9	16.2	------	21.5	20.0	20.8	------	[4] 22.7	[4] 22.7	22.7
8	------	15.5	16.4	16.0	------	19.7	17.7	18.7	------	21.2	22.6	21.9

[1] Rice harvested daily and on alternate days grouped by successive 5-day periods at Stuttgart and 4-day periods at Beaumont.

[2] Supreme Blue Rose at Beaumont.

[3] Average of 4 days.

[4] Single date of cutting.

The consistent decreases in the average moisture content of the rice at both stations, during the successive periods of harvesting, indicate that the rice was immature during the first and mature, or nearly mature, in the last harvesting periods.

At Stuttgart in 1932 and 1933 the moisture content of the rice at the time of threshing was also determined and the results are given by 5-day periods in table 2.

Table 2.—*Percentage of moisture in three varieties of rice at threshing time when harvested by 5-day periods at Stuttgart, Ark., 1932 and 1933* [1]

Period No.	Caloro			Early Blue Rose			Edith		
	1932	1933	Average	1932	1933	Average	1932	1933	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	13.2	17.9	15.6	10.5	13.9	12.2	10.7	13.1	11.9
2	12.8	16.0	14.4	13.4	16.1	14.8	13.4	15.5	14.4
3	13.9	12.6	13.2	12.5	15.3	13.9	12.3	16.2	14.3
4	13.4	12.1	12.8	14.4	12.1	13.3	14.6	14.6	14.6

[1] Rice harvested daily and grouped by successive 5-day periods.

Each variety at threshing time showed an average maximum variation in moisture content for the four periods of from 2.6 to 2.8 percent. Differences also occurred in the moisture content of the three varieties for the same 5-day periods, but the differences were less than that for the same variety harvested in different periods, except for the first 5-day period. These data show that differences in acre yield of from 2 to 3 percent in the same variety and in different varieties may be due to the fact that the rice varies that much in moisture content when threshed.

AIR-DRIED KERNEL WEIGHT

The kernels of immature rice have a high percentage of moisture and, when air-dried, are light in weight, chalky, and do not mill well, whereas mature kernels have a relatively low percentage of moisture and, when air-dried, are heavy, and usually are free of chalk, and unless cracked, mill well.

At Stuttgart, the average air-dried kernel weight on the first dates of harvesting was for Caloro 11.1, for Early Blue Rose 14.2, and for Edith 18.1 milligrams, whereas on the last dates of harvesting the average was for Caloro 23.0, for Early Blue Rose 20.8, and for Edith 24.9 milligrams. The average air-dried kernel weight for the three varieties harvested daily is shown in figure 2. During the first 8 or 9 days of the harvesting periods the average air-dried weight of the kernels increased rapidly, and thereafter the increase was more gradual.

At Beaumont the average air-dried kernel weight on the first dates of harvesting was for Caloro 19.5, for Supreme Blue Rose 18.6, and for Edith 14.6 milligrams, while on the last dates of harvesting the average was for Caloro 23.9, for Supreme Blue Rose 23.7, and for Edith 25.9 milligrams.

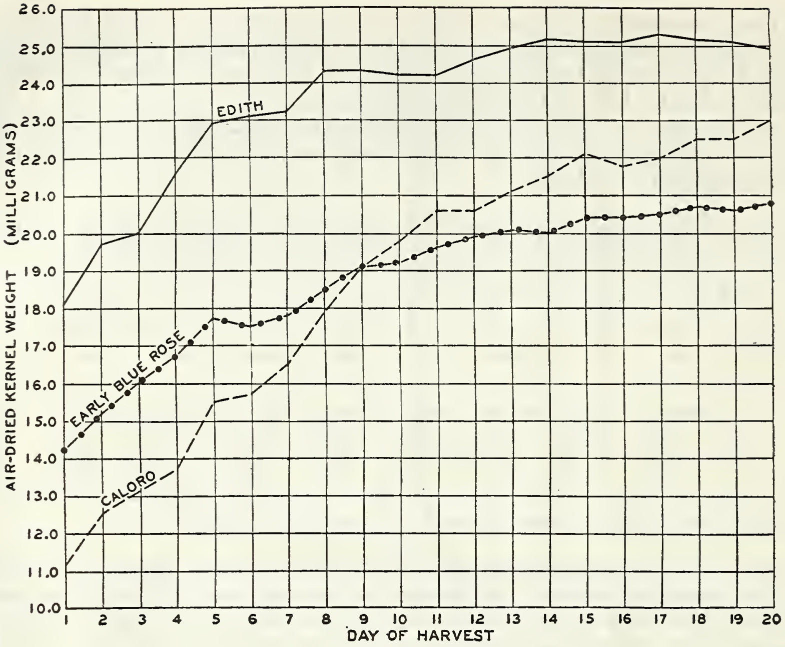

FIGURE 2.—Average air-dried kernel weight of rice harvested daily at Stuttgart, Ark., 1932–34.

Average air-dried kernel weights for the varieties harvested during 5-day periods at Stuttgart, and 4-day periods at Beaumont are shown in table 3.

TABLE 3.—*Average air-dried kernel weight of four varieties of rice harvested by 5-day or 4-day periods at Stuttgart, Ark. and Beaumont, Tex., 1932–34* [1]

Locality and period No.	Caloro				Early Blue Rose [2]				Edith			
	1932	1933	1934	Average	1932	1933	1934	Average	1932	1933	1934	Average
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*
Stuttgart, Ark.:												
1	9.7	16.7	13.0	13.1	14.5	16.7	16.6	15.9	19.5	18.8	23.1	20.5
2	15.2	20.4	17.8	17.8	18.9	19.0	17.4	18.4	24.3	23.1	24.1	23.8
3	20.8	22.8	19.9	21.2	21.0	20.4	18.6	20.0	25.3	24.4	24.6	24.8
4	22.8	23.1	21.2	22.4	22.1	20.2	19.5	20.6	25.9	24.7	24.8	25.1
Beaumont, Tex.: [2]												
1	20.0	20.4	19.8	20.1	25.7	18.6	19.5	21.3	22.2	14.5	17.3	18.0
2	23.2	22.6	22.3	22.7	26.9	23.3	21.8	24.0	24.6	20.6	22.1	22.4
3	24.3	23.5	24.0	23.9	26.6	24.1	23.3	24.7	25.3	24.2	23.9	24.5
4	25.0	23.6	23.8	24.1	26.3	24.8	22.9	24.7	26.1	25.1	24.1	25.1
5	25.0	23.4	24.0	24.1	26.4	24.7	21.3	24.1	26.1	25.8	24.2	25.4
6	24.5	23.5	23.2	23.7	26.6	25.4	22.8	24.9	25.6	26.2	23.9	25.2
7	25.0	23.6	24.4	24.3	26.6	25.9	23.4	25.3	25.8	25.8	24.7	25.4
8	24.8	23.8	23.8	24.1	26.3	25.2	22.8	24.8	25.7	26.9	24.5	25.7

[1] Rice harvested daily and on alternate days grouped by successive 5-day periods at Stuttgart, and 4-day periods at Beaumont.

[2] Supreme Blue Rose at Beaumont.

At Stuttgart the 3-year average air-dried kernel weights show a gradual increase for each variety during successive harvesting periods. The largest increase in kernel weight, however, occurred during the first 10 days of the harvesting periods.

At Beaumont the largest average increase in air-dried kernel weight occurred during the second 4-day periods. There was no marked increase in the average weight of the air-dried kernels on the two last 4-day periods over the preceding periods. This indicates that the rice probably was ripe in the fourth and fifth periods.

YIELD PER ACRE

The average acre yields of the varieties harvested, grouped by 5-day periods at Stuttgart and 4-day periods at Beaumont, are shown in table 4. At Stuttgart the second 5-day periods gave a marked increase in average yield over the first. Each successive period showed a smaller but distinct increase in the average acre yield over the preceding periods. The highest average acre yields for each variety were obtained in the last 5-day periods.

TABLE 4.—*Average yield per acre of four varieties of rice harvested by 5-day or 4-day periods at Stuttgart, Ark., and Beaumont, Tex., 1932–34* [1]

Locality and period No.	Caloro				Early Blue Rose [2]				Edith			
	1932	1933	1934	Average	1932	1933	1934	Average	1932	1933	1934	Average
Stuttgart, Ark.:	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1	694	2, 845	1, 350	1, 630	1, 262	1, 560	1, 062	1, 295	1, 081	2, 067	1, 808	1. 652
2	1, 100	3, 905	2, 243	2. 416	1, 690	2, 169	1, 299	1, 719	1, 283	2, 829	1, 766	1, 959
3	1, 608	4, 154	2, 533	2, 765	1, 956	2, 471	1, 709	2, 045	1, 433	3, 320	1, 887	2, 213
4	1, 735	4, 414	2, 905	3, 018	2, 446	2, 464	1, 647	2, 186	2, 158	3, 397	1, 837	2, 464
Beaumont, Tex.:[2]												
1	2, 442	2, 596	2, 840	2, 626	3, 359	1, 994	2, 264	2, 539	1, 751	1, 389	2, 023	1, 721
2	2, 547	2, 643	2, 978	2, 723	3, 004	2, 343	2, 490	2, 612	1, 752	1, 887	2, 306	1, 982
3	2, 382	3, 212	3, 036	2, 877	3, 047	2, 525	2, 720	2, 764	1, 656	2, 372	2, 416	2, 148
4	2, 747	2, 880	3, 037	2, 888	3, 403	2, 801	2, 678	2, 961	1, 969	2, 580	2, 550	2, 366
5	2, 947	2, 885	3. 310	3, 047	3, 386	2, 577	2, 561	2, 841	2, 311	2, 358	2, 824	2, 498
6	2, 885	2, 914	2, 976	2, 925	3, 092	2, 521	2, 619	2, 744	2, 148	2, 233	2, 670	2, 350
7	2, 832	2, 986	3, 134	2, 984	3, 192	2, 439	2, 982	2, 871	2, 045	2, 377	2, 603	2, 342
8	3, 159	2, 798	3, 278	3, 078	3, 639	2, 979	2, 872	3, 163	2, 310	2, 388	2, 674	2, 457

[1] Rice harvested daily and on alternate days grouped by successive 5-day periods at Stuttgart and 4-day periods at Beaumont.

[2] Supreme Blue Rose at Beaumont.

At Beaumont, owing to greater soil variability, the average acre yields in the different 4-day periods are not so consistent as might be expected. However, the highest average yield for Caloro and Supreme Blue Rose was obtained in the eighth period, or about 32 days after harvesting began, whereas Edith gave the highest average yield in the fifth period, but the yield was nearly as high in the fourth period, or about 16 days after harvesting began.

The marked reduction in average acre yields, as a result of harvesting too early, is clearly shown by the yield data from both stations, but particularly those at Stuttgart. To obtain high acre yields harvesting should be delayed until the rice reaches the proper stage of maturity, which, as indicated by the data presented, ranges from 16 to 20 days after the panicles first turn down, or from 32 to 35 days after first heading.

GRAIN-TO-STRAW RATIO

At Stuttgart the 3-year (1932–34) average grain-to-straw ratio shows that as the crop matured there was a marked increase in the weight of grain in proportion to that of straw. The average ratio by 5-day periods is shown in table 5. There was a marked increase in the proportion of grain to straw in each of the first three successive 5-day periods.

Table 5.—*Ratio of grain to straw in three varieties of rice harvested daily and grouped by successive 5-day periods at Stuttgart, Ark., 1932–34*

Period No.	Caloro				Early Blue Rose				Edith			
	1932	1933	1934	Average	1932	1933	1934	Average	1932	1933	1934	Average
1	1:4.3	1:3.2	1:3.6	1:3.7	1:2.8	1:4.6	1:5.4	1:4.3	1:3.0	1:3.2	1:2.9	1:3.0
2	1:2.5	1:2.2	1:2.2	1:2.3	1:2.3	1:4.1	1:4.1	1:3.5	1:2.8	1:3.1	1:2.7	1:2.9
3	1:1.5	1:1.7	1:1.7	1:1.6	1:1.9	1:3.1	1:3.2	1:2.7	1:2.4	1:2.8	1:2.6	1:2.6
4	1:1.5	1:1.7	1:1.8	1:1.7	1:1.7	1:3.1	1:3.3	1:2.7	1:1.9	1:2.5	1:2.5	1:2.3

PERCENTAGE OF GERMINATION

At Stuttgart the percentage germination of the rice harvested daily was determined and the results are shown in figure 3. The percentage of germination of each variety increased rapidly during the first 6 to 8 days of the harvesting periods, and during the next 4 or 5 days there was a slight increase in germination, but after the twelfth day the percentage of germination remained about constant. The average percentage of germination reached its maximum before the rice was sufficiently mature to produce maximum acre yields but there was no consistent decrease in germination as the rice matured. Therefore, rice harvested at the proper stage of development to produce high acre yields of good milling quality also will be satisfactory for seed purposes.

The annual and average percentage of germination, grouped by 5-day periods, is shown in table 6. The varieties show a consistent increase in the average percentage of germination in each successive harvesting period.

Table 6.—*Percentage germination of three varieties of rice harvested daily and grouped by successive 5-day periods at Stuttgart, Ark., 1932–34*

Period No.	Caloro				Early Blue Rose				Edith			
	1932	1933	1934	Average	1932	1933	1934	Average	1932	1933	1934	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	14.5	61.1	25.6	33.7	42.2	72.8	63.0	59.3	70.7	68.5	89.0	76.1
2	48.9	89.8	82.8	73.8	66.9	87.0	79.7	77.9	92.3	92.0	92.9	92.4
3	85.5	92.0	91.1	89.5	85.6	94.0	89.6	89.7	95.7	94.7	95.8	95.4
4	87.8	90.3	95.8	91.3	90.4	96.4	93.1	93.3	96.4	96.0	95.8	96.1

MILLING QUALITY

At Stuttgart the percentage of whole kernels in the test for milling quality increased rapidly during the first 10 days of the harvesting periods, and thereafter the increase was more gradual but continued to the end of the harvesting periods. The average percentage of whole kernels obtained on each date of harvesting is shown in figure 4.

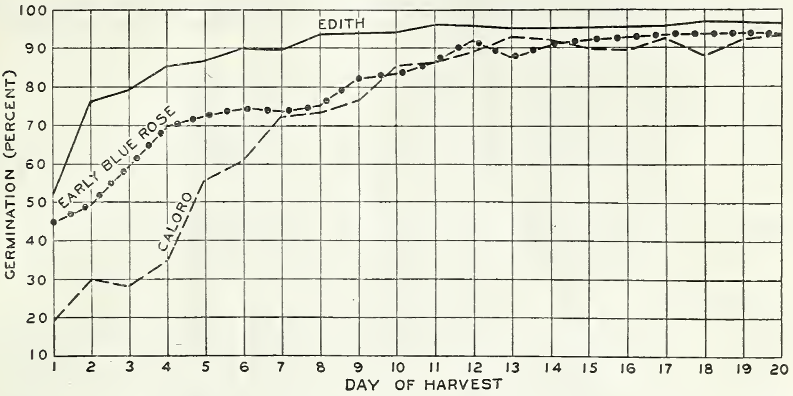

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FIGURE 3.—Average percentage of germination of rice harvested daily at Stuttgart, Ark., 1932–34.

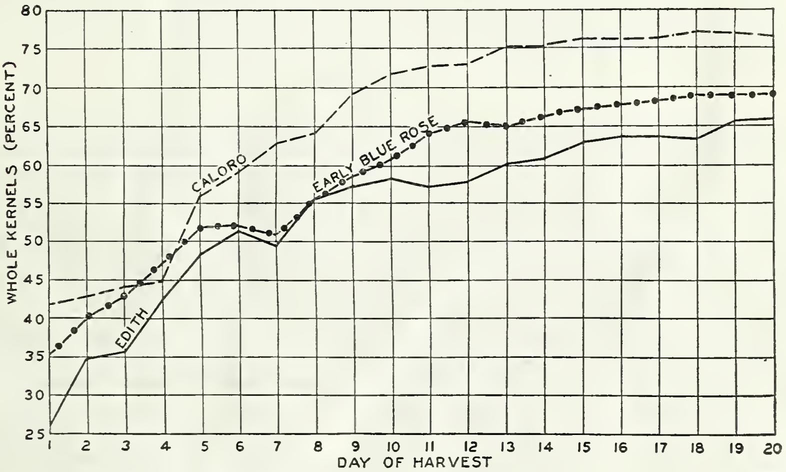

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FIGURE 4.—Percentage of whole kernels obtained in the test for milling quality of rice harvested daily at Stuttgart, Ark., 1932–34.

The average percentage of whole kernels grouped by 5-day periods at Stuttgart and by 4-day periods at Beaumont, is shown in table 7.

At Stuttgart there was a consistent increase in the percentage of whole kernels in each successive harvesting period.

At Beaumont the highest average percentage of whole kernels for Caloro and Supreme Blue Rose was obtained in the third 4-day periods, and for Edith in the last period. There was little difference, however, in the average percentage of whole kernels in each of the last five periods which indicates that the rice was fairly well matured in each of these periods, and apparently was not severely damaged by checking. In this experiment the land was not drained until after the last harvesting date, and the fact that the land was still submerged may have prevented the rice from checking when ripe or overripe.

TABLE 7.—*Percentage of whole kernels obtained in the test for milling quality of four varieties of rice harvested by 4-day or 5-day periods at Stuttgart, Ark. and Beaumont, Tex., 1932–34* [1]

Locality and period No.	Caloro				Early Blue Rose [2]				Edith			
	1932	1933	1934	Average	1932	1933	1934	Average	1932	1933	1934	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Stuttgart, Ark.:												
1	32.4	57.6	47.7	45.7	30.0	56.6	43.7	43.4	29.9	30.5	51.5	37.3
2	52.9	72.4	70.7	65.3	45.7	66.3	54.6	55.5	45.7	53.2	64.2	54.4
3	70.9	77.6	74.6	74.4	60.3	71.2	65.5	65.7	54.4	57.3	67.3	59.7
4	76.3	77.9	75.5	76.5	65.8	71.8	67.7	68.5	64.0	59.9	68.8	64.2
Beaumont, Tex.:[2]												
1	73.3	76.9	59.3	69.8	73.8	57.0	59.2	63.3	56.3	39.3	35.5	43.7
2	78.5	79.1	69.7	75.8	76.2	69.4	64.1	69.9	67.9	63.3	58.8	63.3
3	80.1	79.2	74.1	77.8	76.8	71.9	68.4	72.4	71.5	71.0	65.3	69.3
4	79.9	79.5	71.9	77.1	70.0	73.9	65.9	69.9	70.0	71.9	65.3	69.1
5	78.6	78.2	70.8	75.9	70.5	72.1	64.3	69.0	67.2	71.8	66.4	68.5
6	77.8	78.0	70.3	75.4	72.3	73.0	66.7	70.7	69.1	73.5	65.1	69.2
7	77.3	75.7	73.7	75.6	64.9	73.4	68.0	68.8	61.9	71.9	69.0	67.6
8	78.7	71.7	71.1	73.8	68.9	71.5	65.9	68.8	74.4	72.7	65.8	71.0

[1] Rice harvested daily and on alternate days grouped by 5-day periods at Stuttgart and 4-day periods at Beaumont.

[2] Supreme Blue Rose at Beaumont.

CORRELATIONS

At Stuttgart each year there was a highly significant negative correlation between the percentage of moisture in the rice at harvest time and the acre yield, weight of air-dried kernels, percentage of whole kernels, and percentage of germination (table 8), except for acre yield and weight of kernels for Edith in 1934. This relationship is to be expected, for, as has been stated, immature rice has a high percentage of moisture, the kernels are soft and chalky, are low in air-dried weight, and are easily broken in milling, and they do not germinate well. On the other hand, there was each year a highly significant positive correlation between the air-dried weight of kernels at harvest time and the acre yield, percentage of whole kernels, and the percentage of total rice, except for weight of air-dried kernels and acre yield for Edith in 1934. The high positive correlation between these factors indicates that well-matured kernels are heavy and when harvested at this stage of development the acre yield and milling quality are both high.

TABLE 8.—*Correlation coefficients between the factors studied in the date-of-harvesting experiment at Stuttgart, Ark., and at Beaumont, Tex., 1932–34* [1]

STUTTGART, ARK.

A	*X*	Caloro			Early Blue Rose [2]			Edith		
		1932	1933	1934	1932	1933	1934	1932	1933	1934
Percentage of moisture at harvest.	Acre yield of grain	−0.89	−0.96	−0.93	−0.68	−0.91	−0.86	−0.82	−0.93	**−0.21
Do	Air-dried weight of kernels.	−.99	−.99	−.97	−.98	−.98	−.90	−.92	−.98	**+.07
Do	Percentage of whole kernels.[3]	−.97	−.98	−.94	−.98	−.98	−.94	−.94	−.98	−.86
Do	Percentage of germination.	−.96	−.90	−.93	−.94	−.98	−.92	−.82	−.89	−.83
Air-dried weight of kernels.	Acre yield of grain	+.89	+.94	+.98	+.65	+.93	+.88	+.67	+.92	**−.10
Do	Percentage of whole kernels.[3]	+.99	+.98	+.96	+.98	+.99	+.96	+.94	+.98	+.90
Do	Percentage of total rice.[3]	+.98	+.95	+.98	+.99	+.98	+.94	+.97	+.96	+.81

BEAUMONT, TEX.

Percentage of moisture at harvest.	Acre yield of grain	-------	**−0.35	*−0.52	-------	−0.76	−0.76	-------	−0.85	−0.84
Do	Air-dried weight of kernels.	-------	−.70	−.80	-------	−.93	−.74	-------	−.97	−.80
Do	Percentage of whole kernels.[3]	-------	*+.53	−.65	-------	−.81	−.65	-------	−.89	−.80
Air-dried weight of kernels.	Acre yield of grain	*+0.51	*+.60	*+.52	*−0.57	+.74	+.80	*+0.54	+.90	+.85
Do	Percentage of whole kernels.[3]	+.79	**−.02	+.95	**+.19	+.95	+.93	+.63	+.96	+.98
Do	Percentage of total rice.[3]	+.77	+.80	+.76	**+.26	+.97	+.94	+.88	+.93	+.97

[1] All coefficients not starred were highly significant, those with one star were significant, and those with two stars were not significant. See Fisher, R. A., Statistical Methods for Research Workers.
[2] Supreme Blue Rose at Beaumont.
[3] Results of shelling tests.

At Beaumont in 1933 and 1934 either highly significant or significant negative correlations between the percentage of moisture in the rice at harvest time and the acre yield, weight of the air-dried kernels, and percentage of whole kernels were obtained, except for Caloro in which there was a significant positive correlation between the percentage of moisture and whole kernels and an insignificant correlation between percentage of moisture at harvest and acre yield (table 8) in 1933. These exceptions probably were due to the fact that Caloro was harvested later in 1933 than in 1934 and therefore the rice when first harvested was more nearly mature. Highly significant or significant positive correlations in 1932, 1933, and 1934 were obtained between the weight of the air-dried kernels and acre yield, percentage of whole kernels, and the percentage of total rice, except for Supreme Blue Rose in which there was a significant negative correlation between weight of air-dried kernels and acre yield, and insignificant correlations between weight of kernels and percentage of whole kernels and total rice in 1932, and also for percentage of whole kernels for Caloro in 1933. Variable acre yields and irregular maturity of Supreme Blue Rose in 1932 were probably responsible for the negative correlation between weight of the air-dried kernels and acre yield, and lack of a significant correlation between the weight of the air-dried kernels and percentage of whole kernels.

STUDIES AT FARM FIELDS

A series of investigations were conducted by the Bureau of Agricultural Economics during the harvesting seasons of 1931 and 1932 in Texas, of 1933 in Louisiana, and of 1935 in Arkansas to ascertain the stage of maturity at which rough rice, when harvested, will produce the highest percentage of whole kernels when milled.

Uniform areas were selected in farm rice fields and a small plot of each of several varieties was harvested and threshed each day, beginning when the rice was distinctly immature and continuing until after it was fully ripe. The moisture content of the rice when harvested was determined, and the samples were permitted to dry to a moisture content of about 14 percent. This is the moisture content at which rice can be milled commercially to best advantage. The samples were then tested for milling quality by means of the Smith shelling device. These samples showed a distinct improvement in milling quality as the rice came into maturity and also showed the bad effects of allowing the rice to stand uncut too long.

RESULTS FROM FARM FIELDS

MOISTURE CONTENT

The average percentage of moisture in Blue Rose and Early Prolific when harvested and the average percentage of whole kernels and total rice in tests for milling quality by 5-day periods for 1931 and 1932 in Texas, 1933 in Louisiana, and 1935 in Arkansas, are shown in table 9.

The data show essentially the same general relationship between the average moisture content of the rice at harvest time and the average yield of whole kernels for both varieties in each State in all years. The average percentage of whole kernels obtained in the test for milling quality, for the first 5-day periods, ranged from 57.7 in 1935 to 74.3 in 1931—both with Blue Rose. Each year the highest average percentage of whole kernels was obtained from rice with an average moisture content of from 22.7 to 27.7 percent at harvest time. Usually the average yields of whole kernels decreased rather rapidly when the average moisture content of the rice at harvest time was 20 percent or below. For example, Blue Rose in 1935 with an average moisture content of 22.7 percent at harvest gave an average mill yield of 73.4 percent of whole kernels, and when the average moisture content at harvest was 15.0 percent the average yield of whole kernels was only 59.5 percent.

TABLE 9.—*Percentage of moisture in rice at harvest time, whole kernels, and total rice obtained in tests for milling quality of two varieties harvested at different periods, grouped by 5-day periods in Texas, 1931, and 1932, Louisiana, 1933, and Arkansas, 1935*

Variety and date of harvest by 5-day periods	Texas, 1931, average percentage of—			Date of harvest by 5-day periods	Texas, 1932, average percentage of—			Date of harvest by 5-day periods	Louisiana, 1933, average percentage of—			Date of harvest by 5-day periods	Arkansas, 1935, average percentage of—		
	Moisture at harvest	Whole kernels	Total rice		Moisture at harvest	Whole kernels	Total rice		Moisture at harvest	Whole kernels	Total rice		Moisture at harvest	Whole kernels	Total rice
Blue Rose:	*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Sept. 23–27	26.3	74.3	78.1	Sept. 13–17	28.4	70.5	76.6	Sept. 17–21	29.0	63.3	73.4	Sept. 28–Oct. 2	29.5	57.7	73.3
Sept. 28–Oct. 2	24.8	75.3	78.3	Sept. 18–22	27.7	75.9	78.1	Sept. 22–26	27.0	70.3	75.3	Oct. 3–7	29.2	63.8	75.3
Oct. 3–7	23.1	74.7	78.1	Sept. 23–27	26.0	74.6	77.7	Sept. 27–Oct. 1	24.5	71.0	76.1	Oct. 8–12	27.6	66.1	74.9
Oct. 8–12	20.8	71.7	77.6	Sept. 28–Oct. 2	24.6	74.5	77.5	Oct. 2–6	21.3	67.8	75.8	Oct. 13–17	23.9	72.6	76.5
Oct. 13–17	17.1	62.7	78.9	Oct. 3–7	22.3	73.7	77.2	Oct. 7–11	18.3	60.4	75.5	Oct. 18–22	22.7	73.4	76.6
				Oct. 8–12	20.2	73.7	77.8	Oct. 12–16	18.3	55.4	77.4	Oct. 23–27	21.9	71.7	76.7
				Oct. 13–17	16.1	71.9	77.9	Oct. 17–21	16.6	49.7	76.0	Oct. 28–Nov. 1	19.8	68.1	76.1
												Nov. 2–6	18.5	67.6	76.2
												Nov. 7–11	18.3	66.4	75.6
												Nov. 12–16	17.8	64.2	75.1
												Nov. 17–21	15.0	59.5	75.8
Early Prolific:															
Aug. 24–28	27.8	74.1	77.7	Aug. 13–17	30.5	65.4	74.8	Aug. 18–22	31.1	64.6	69.4	Sept. 16–20	28.5	61.6	73.9
Aug. 29–Sept. 2	24.8	74.2	77.4	Aug. 18–22	26.7	67.1	75.4	Aug. 23–27	27.8	68.6	73.5	Sept. 21–25	26.0	68.2	75.7
Sept. 3–7	21.9	71.5	77.1	Aug. 23–27	25.2	69.1	75.3	Aug. 28–Sept. 1	26.2	70.7	74.9	Sept. 26–30	23.4	63.9	75.1
Sept. 8–12	21.2	54.8	75.7	Aug. 28–Sept. 1	22.3	67.9	75.4	Sept. 2–6	21.7	69.2	76.1	Oct. 1–5	21.6	63.9	74.8
Sept. 13–17	21.0	51.8	76.0	Sept. 2–6	19.7	64.3	75.4	Sept. 7–11	19.4	61.3	75.6	Oct. 6–10	21.5	66.4	75.6
Sept. 18–22	21.4	55.8	76.1	Sept. 7–11	15.7	53.2	75.6	Sept. 12–16	17.0	52.9	76.1	Oct. 11–15	20.1	65.2	76.1
Sept. 23–27	15.4	49.4	77.9	Sept. 12–16	15.1	48.6	75.2					Oct. 16–20	18.4	58.7	76.7
												Oct. 21–25	19.1	58.5	77.3
												Oct. 26–30	17.9	56.5	76.6
												Oct. 31–Nov. 4	15.3	54.9	75.2
												Nov. 5–9	17.3	55.0	75.1
												Nov. 10–14	16.8	49.2	72.6

The daily percentage of moisture, in Blue Rose at harvest, from September 28 to November 22, the percentage of whole kernels and of total rice in the tests for milling quality in 1935 are shown in figure 5.

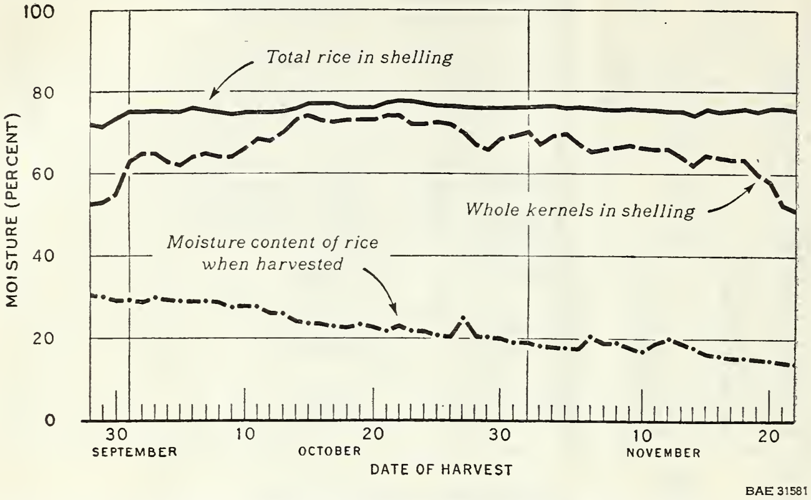

FIGURE 5.—Daily percentage of moisture in Blue Rose rice when harvested from September 28 to November 22, 1935, and the percentage of whole kernels and of total rice in the test for milling quality. (The milling-quality tests were made when the samples had been dried to a moisture content of approximately 14 percent.)

On September 28 the moisture content of Blue Rose rice when harvested was 30.5 percent and the yield of whole kernels in the test for milling quality was 52.5 percent, and on November 22 the moisture content, when harvested, was 14 percent and the yield of whole kernels 51 percent. From October 14 to 26 the moisture content of the rice, when harvested, ranged from 24.0 to 20.2 percent and the yield of whole kernels ranged from 72.0 to 74.1 percent. It is apparent from the data presented in figure 5 that in 1935 the milling quality of Blue Rose was adversely affected when harvested too early, but that the rice was of high milling quality when harvested at full maturity.

The average percentage of moisture at harvest time, and the average percentage of whole kernels and total rice obtained in the tests for milling quality by 5-day periods for Fortuna in 1931 in Texas, for Rexoro and Shoemed in 1933 in Louisiana, and for Edith and Caloro in 1935 in Arkansas are shown in table 10.

The data show that the highest average yields of whole kernels were obtained when the rice at harvest contained an average moisture content of from 22.1 percent for Shoemed to 26.4 percent for Caloro. The average yields of whole kernels for Fortuna, Shoemed, and Edith decreased rapidly when the average moisture content of the rice at harvest time was as low as about 18 percent, whereas Rexoro and Caloro gave comparatively high yields of whole kernels even when the rice contained an average of less than 15 percent of moisture. In other words, Rexoro and Caloro still gave comparatively high average yields of whole kernels even though the crop was ripe or overripe when harvested.

TABLE 10.—*Percentage of moisture in rice at harvest time, whole kernels, and total rice obtained in tests for milling quality of five varieties, harvested at different periods grouped by 5-day periods in Texas, 1931, Louisiana, 1933, and Arkansas, 1935*

Date of harvest by 5-day periods	Fortuna, Texas, 1931, average percentage of—			Date of harvest by 5-day periods	Rexoro, Louisiana, 1933, average percentage of—			Date of harvest by 5-day periods	Shoemed, Louisiana, 1933, average percentage of—		
	Moisture at harvest	Whole kernels	Total rice		Moisture at harvest	Whole kernels	Total rice		Moisture at harvest	Whole kernels	Total rice
	Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*	*Pct.*		*Pct.*	*Pct.*	*Pct.*
Sept. 17–21	25.0	60.9	75.8	Sept. 20–24	25.6	46.3	71.5	Aug. 27–31	28.3	64.6	74.2
Sept. 22–26	17.7	48.8	76.8	Sept. 25–29	20.9	45.7	73.4	Sept. 1–5	22.1	66.3	76.1
Sept. 27–Oct. 1	14.8	34.0	78.0	Sept. 30–Oct. 4	17.0	45.5	75.5	Sept. 6–10	17.2	53.7	76.7
				Oct. 5–7 [1]	14.4	42.9	75.2	Sept. 11–15	17.6	52.1	75.8
								Sept. 16–19 [2]	14.6	34.0	78.2

Date of harvest by 5-day periods	Edith, Arkansas, 1935, average percentage of—			Date of harvest by 5-day periods	Caloro, Arkansas, 1935, average percentage of—		
	Moisture at harvest	Whole kernels	Total rice		Moisture at harvest	Whole kernels	Total rice
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Sept. 12–16	28.9	61.9	76.2	Sept. 10–14	28.4	71.9	76.4
Sept. 17–21	24.6	65.0	77.7	Sept. 15–19	26.4	74.2	77.6
Sept. 22–26	20.8	61.5	77.3	Sept. 20–24	22.1	72.5	77.5
Sept. 27–Oct. 1	21.4	54.7	77.4	Sept. 25–29	21.5	71.4	78.0
Oct. 2–6	20.3	56.0	78.3	Sept. 30–Oct. 4	18.7	70.5	77.7
Oct. 7–11	19.1	58.4	78.4	Oct. 5–9	16.3	71.6	76.4
Oct. 12–16	17.4	50.0	77.8	Oct. 10–13 [2]	14.8	69.8	78.8
Oct. 17–21	16.9	42.9	77.5				
Oct. 22–26	18.0	41.0	77.7				

[1] Average of 3 days.
[2] Average of 4 days.

The daily average percentage of moisture in the Edith variety at harvest from September 12 to October 26 and the average percentage of whole kernels and total rice in the test for milling quality in 1935 are shown in figure 6.

The moisture content of the Edith variety when harvested on September 12 was 30 percent, and the yield of whole kernels in the test for milling quality was 61.8 percent; on October 26 the moisture content at harvest was 14 percent and the yield of whole kernels was 38.0 percent. The maximum yield of whole kernels, 66 percent, was obtained on September 17 and 18 when the moisture content of the rice when harvested ranged from 24.2 to 26.0 percent.

The data presented in figure 6 clearly show the detrimental effect on milling quality of allowing Edith to become overripe before harvesting. Its moisture content when harvested from October 13 to 26 ranged from 18.1 to 14.0 percent, except when it rained, and the yield of whole kernels during this period ranged from 38 to 50 percent.

The daily average percentage of moisture in rice of the Caloro variety at harvest from September 10 to October 13, and the daily average percentage of whole kernels and of total rice in the test for milling quality in 1935 are shown in figure 7.

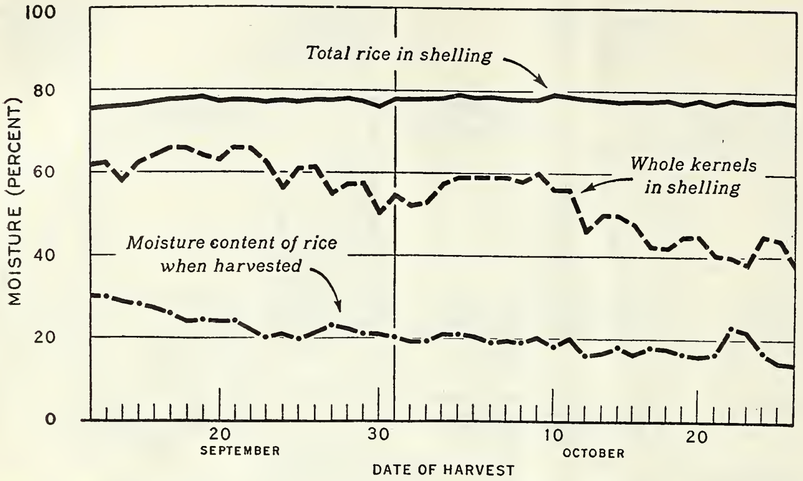

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FIGURE 6.—Daily percentage of moisture in the Edith when harvested from September 12 to October 26, 1935, also the percentage of whole kernels and of total rice in the test for milling quality. (The milling-quality tests were made when the samples had been dried to a moisture content of approximately 14 percent.)

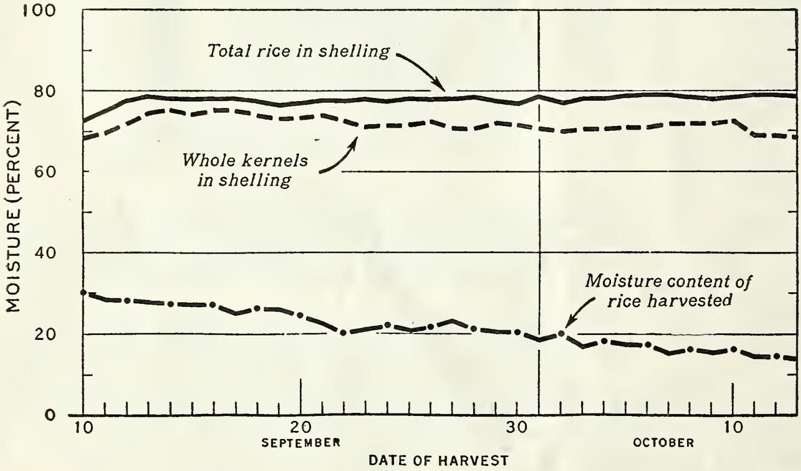

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FIGURE ..—Daily percentage of moisture in Caloro when harvested from September 10 to October 13, 1935, also the percentage of whole kernels and of total rice in the test for milling quality. (The milling-quality tests were made when the samples had been dried to a moisture content of approximately 14 percent.)

The moisture content of the Caloro variety when harvested on September 10 was 30.2 percent, and the yield of whole kernels was 68.2 percent. On October 13 the moisture content when harvested was 14 percent and the yield of whole kernels was 68.6 percent. The yield of whole kernels was almost identically the same for the two dates in spite of the fact that the moisture content at harvest differed by 16.2 percent. The data in figure 7 show that the milling quality of Caloro is not so seriously affected by an excess or a deficiency of moisture in the rice at harvest as are Blue Rose, and to a greater extent Edith, and most of the other medium- and long-grain varieties. The highest yields of whole kernels for Caloro were, however, obtained when the rice at harvest contained from 25.1 to 27.4 percent of moisture.

DISCUSSION BASED ON RESULTS

The percentage of moisture in the rice decreased rapidly during the first 8 to 10 days of the harvesting periods; thereafter the decrease was more gradual. A marked increase in the yield per acre, in weight of the air-dried kernels, and improvement in milling quality also occurred during these periods. Thereafter there was a more gradual increase in the yield per acre and in milling quality, up to the time the rice was fully matured. Figures 8 and 9 show graphically the relationship between the percentage of moisture in the rice when harvested daily and the air-dried kernel weight, which is highly correlated with acre yield. They also show the percentage of whole kernels in the test for milling quality.

When the moisture content of standing rice is as low as 16 to 20 percent the crop is usually overripe. Although the acre yield is as high as or higher if rice is harvested at this stage than if it is harvested earlier, the milling quality is not likely to be so good because the kernels check and this reduces the percentage of whole kernels obtained in milling. Therefore, the two factors that appear to be most closely associated with high acre yields and high milling quality are the moisture content of the rice at harvest time and the air-dried weight of the kernels.

Both the moisture content of the rice and the kernel weight can be determined quickly and accurately. Either determination would make it possible to decide whether the rice is mature enough to produce high acre yields of high milling quality. The percentage of moisture is the more accurate factor to use because it readily indicates the degree of ripeness. Information is lacking concerning the average air-dried kernel weight of varieties grown under different conditions.

The acre yield is apparently not decreased, except by shattering and lodging, when the harvest is delayed until the rice on plants has a moisture content of from 16 to 20 percent, but standing rice with such low moisture content is likely to check and thus give a low percentage of whole kernels when milled. The results of the studies indicate that, after the crop has been harvested when it contains from 28 to 23 percent of moisture, the rice should be allowed to cure properly in the shock, or the moisture content should be reduced gradually by artificial means.

The effect of a high moisture content on acre yield and the air-dried kernel weights is illustrated by Caloro at Stuttgart in 1933. Caloro on the first harvesting date had a moisture content of 52.9 percent, the average air-dried kernel weight was 14.3 milligrams, and the yield was 55.2 bushels per acre; whereas 20 days later, on the last date of harvesting, the moisture content was 27.9 percent, the air-dried kernel weight was 23.3 milligrams, and the yield was 100.4 bushels per acre.

The effect of a low moisture content on milling quality is illustrated by Blue Rose on farm fields in Texas in 1931. Blue Rose on the first date of harvesting (September 23) had a moisture content of 26.4 percent, and the percent of whole kernels in the milling-quality test was 75.6 percent; whereas on October 19 the moisture content was 13.4 percent and the percent of whole kernels was 52.7.

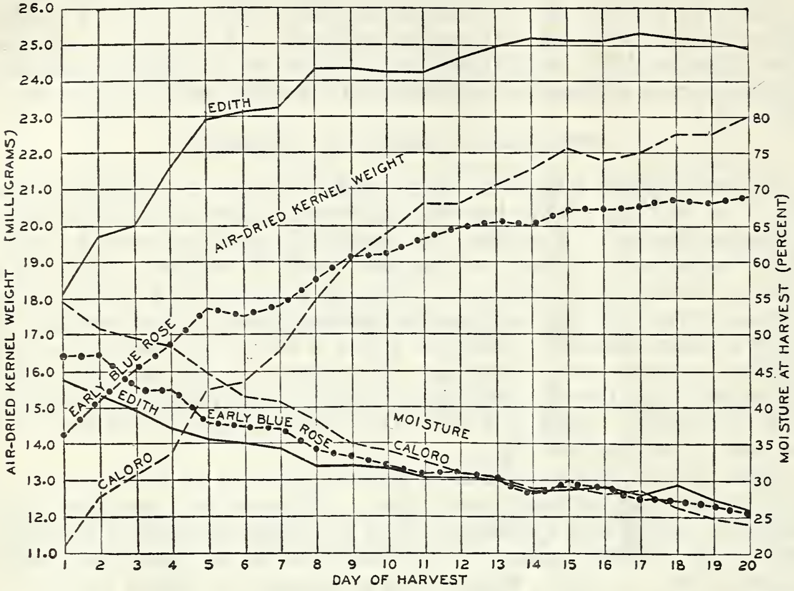

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FIGURE 8.—Relationship between the percentage of moisture in the rice when harvested daily and the air-dried kernel weight at Stuttgart, Ark., 1932–34.

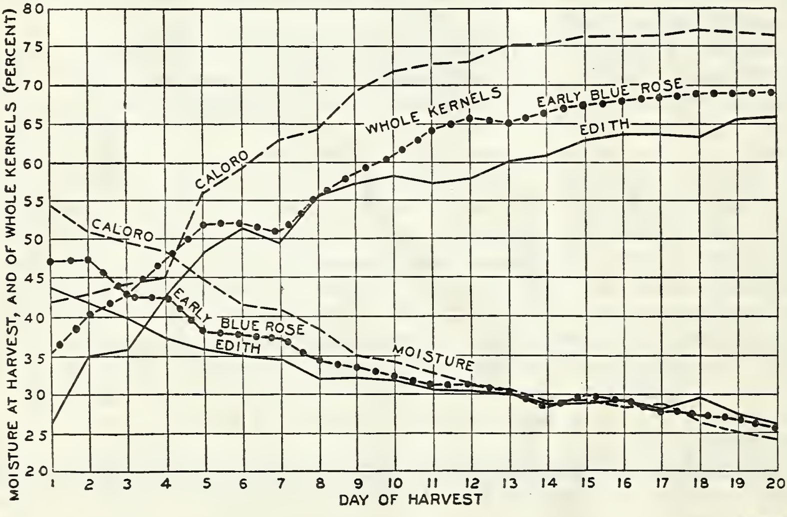

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FIGURE 9.—Relationship between the percentage of moisture in the rice when harvested daily and percentage of whole kernels at Stuttgart, Ark., 1932–34.

CONCLUSIONS

The results of the studies indicate that, to obtain maximum acre yields of high milling quality, the crop should be harvested when the moisture content of the standing rice ranges from about 28 to 23 percent. The rice of the varieties studied normally reaches this moisture content in from 16 to 20 days after the panicles start to turn down, or from 30 to 35 days after the rice begins to head. At this time the kernels are fully mature in the upper portions of the panicles and are in the hard-dough stage at the base of the panicles. Few, if any, chalky kernels are found in rice that has been harvested at this stage of maturity.

As the moisture in the standing rice decreased, there was a marked increase in the air-dried weight of the kernels, in the yield per acre, in the percentage of whole kernels obtained in the test for milling quality, and in germination.

Harvesting operations that are started when the rice has reached the proper stage of maturity for cutting should proceed rapidly in order that all of the crop will be cut before it becomes too ripe. On warm dry days the loss of moisture from the grain of standing rice is rapid; on rainy days and on days of high humidity the loss of moisture may be greatly retarded or entirely stopped—in fact, the kernels may even take up moisture.

Moisture tests of representative samples from the standing rice can be readily made to find out when the crop has reached the proper stage of maturity for harvesting. Moisture tests can be obtained by growers in almost all sections of the rice producing areas in the South at rice inspection laboratories, rice mills, rice warehouses, and growers' associations.

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